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SERVICE REPORT

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

MEASUREMENT OF DISTORTION IN SECOND EXPERIMENTAL CONTROL ROD

FOR ARGONNE NAVAL REACTOR WITH CONSTANT TRANSVERSE

TEMPERATURE GRADIENT AND UNIFORM LONGITUDINAL

TEMPERATURE DISTRIBUTION

By T. F. Nagey and A. F. Lietzke

SUMMARY

Measurements were made of the thermal distortion of a stainless-
steel clad, cadmium-silver reactor control rod furnished by the Argonne
National Laboratory. The temperature pattern in the rod was as follows:
At each cross section, the temperature at the center of the rod was
approximately 430° F and a nominal temperature difference of about 40° F
was maintained between one pair of opposite tips. This transverse
pattern was maintained approximately constant along the rod length. The
tests were repeated with the transverse temperature gradient rotated
180° with respect to the rod.

The maximum reduction in clearance caused by thermal distortion was
0.203 inch. This reduction in clearance was approximately independent
of the direction of the transverse temperature gradient.

INTRODUCTION

Determinations of the thermal distortion of a stainless-steel clad,
cadmium-silver core control rod for the Argonne Naval reactor were made
at the NACA Lewis laboratory. The control rod was furnished by the
Argonne National Laboratory. Distortion measurements with estimated
temperature patterns intended to simulate certain reactor operating
conditions are presented in references 1 and 2. Measurements are pre-
sented herein of thermal distortion with a temperature pattern which is
not intended to simulate any particular reactor operating condition, but
to show the effect of maximum transverse temperature gradients (as limited
by test facilities) with constant longitudinal temperature.

The control rod used in this investigation is the one discussed in
reference 2.

APPARATUS

The test setup as used for this investigation is the same as that described in reference 2. The following paragraphs contain a brief description of the apparatus used:

Control rod. - The control rod consisted of a 25-75 percent cadmium-silver core, clad with stainless steel. The rod cross section is in the shape of a cross having a span of 4 inches. The total arm thickness is 7/32 inch consisting of 1/8-inch core alloy with a stainless-steel cladding thickness of 3/64 inch. The over-all length of the rod is 53.75 inches.

The rod had several cracks in the welded portions of the cross tips as reported in reference 2. These failures did not increase in size during the tests reported herein.

Method of supporting control rod. - The control rod was mounted vertically with the fixed end at the bottom. The vise which holds the control rod was bolted indirectly to the mounting plate through insulating material to reduce the heat flow to the mounting plate. Strain gages were located near the clamped end to ensure freedom from initial stress while clamping.

Method of obtaining temperature distribution. - The control rod was heated by a 75 KVA induction heater as in references 1 and 2. The axial temperatures were held constant by adjusting the axial spacing of the heater coil turns. The transverse temperature gradients were obtained by arranging the heater coil and control rod nonconcentrically and by a series of air jets mounted along the rod and directed toward the center of the cross. The air-cooling system is described in reference 2.

Method of measuring distortion. - Distortion of the rod was measured by dial indicators as in references 1 and 2. Normally two indicators were located at each tip of the cross in five transverse stations as given in table II. The indicators were mounted on four supports which were fastened to the same mounting plate as the control rod. The supports were insulated to prevent thermal conduction and were protected from radiation. They were also instrumented in order to indicate any motion. Fused quartz rods about 12 inches in length were used to transmit the motion of the control rod to the dial indicators. The reproducibility of the indicator readings was ± 0.002 inch.

RESULTS AND DISCUSSION

Summary of data. - The temperature pattern used as a basis for the present tests was obtained from the Argonne National Laboratory. The

temperature pattern in the rod was as follows: At each cross section
the temperature at the center of the rod was approximately 430° F and a
nominal temperature difference of about 40° F was maintained between one
pair of opposite tips. This transverse pattern was maintained approxi-
mately constant along the rod length. The test was repeated with the
transverse temperature gradient rotated 180° with respect to the rod.

The thermocouple locations and the corresponding surface temperatures
obtained experimentally are listed in table I. As indicated in the
diagrams, the distance of the transverse station from the free end of the
control rod in inches is represented by Z, and the thermocouple locations
at each value of Z are designated by numbers from 1 to 16. As indi-
cated in the table, 16 thermocouples were not installed at all values
of Z.

The control-rod distortion resulting from the temperatures of
table I are shown in table II. The displacement at each point on the
rod is fixed by the values of Δx and Δy with their proper signs.
The values are with reference to the unheated position of the rod.

In tables I and II, run 2 is a repeat of run 1, and run 3 represents
approximately the same longitudinal temperature pattern as in runs 1 and
2 with the transverse temperature gradient rotated 180° with respect
to the rod.

Distortion of control rod. - The displacement of the tips of the
control-rod arms are plotted in figures 1 and 2. Figure 2 indicates the
distortion with the same nominal temperature pattern as for figure 1, but
with the transverse temperature pattern rotated 180° with respect to the rod.

The distortions shown in figures 1 and 2, as to be expected, are
opposite in sign. The plots indicate that the rod distorts about the
same amount in either direction. Although the actual temperature
patterns are somewhat different for the two tests (see table I, where
runs 1 and 2 represent the pattern for fig. 1 and run 3 for fig. 2),
the maximum distortion of the center of the rod agrees within 0.006 inch
in the Δy direction and within 0.010 inch in the Δx direction. The
maximum reduction in clearance shown in both figures 1 and 2 is about
0.203 inch.

SUMMARY OF RESULTS

The results of tests on the distortion of a stainless-steel clad,
silver-cadmium reactor control rod under the influence of a constant
transverse temperature gradient and a uniform longitudinal temperature
distribution can be summarized as follows:

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1. The maximum reduction in clearance obtained in the tests was 0.203 inch.

2. When the test was repeated with the transverse temperature pattern rotated 180° with respect to the rod axis, the amount of the reduction in clearance was unchanged.

Lewis Flight Propulsion Laboratory
    National Advisory Committee for Aeronautics
        Cleveland, Ohio, August 9, 1951

REFERENCES

1. Nagey, T. F., and Lietzke, A. F.: Measurement of Distortion in First Experimental Control Rod for Argonne Naval Reactor. NACA RM E51A30, 1951.

2. Lietzke, A. F., and Nagey, T. F.: Measurement of Distortion in Second Experimental Control Rod with Temperature Patterns Simulating Shim Rod Out and Shim Rod 50 Percent Inserted for Argonne Naval Reactor. NACA RM E51E25, 1951.
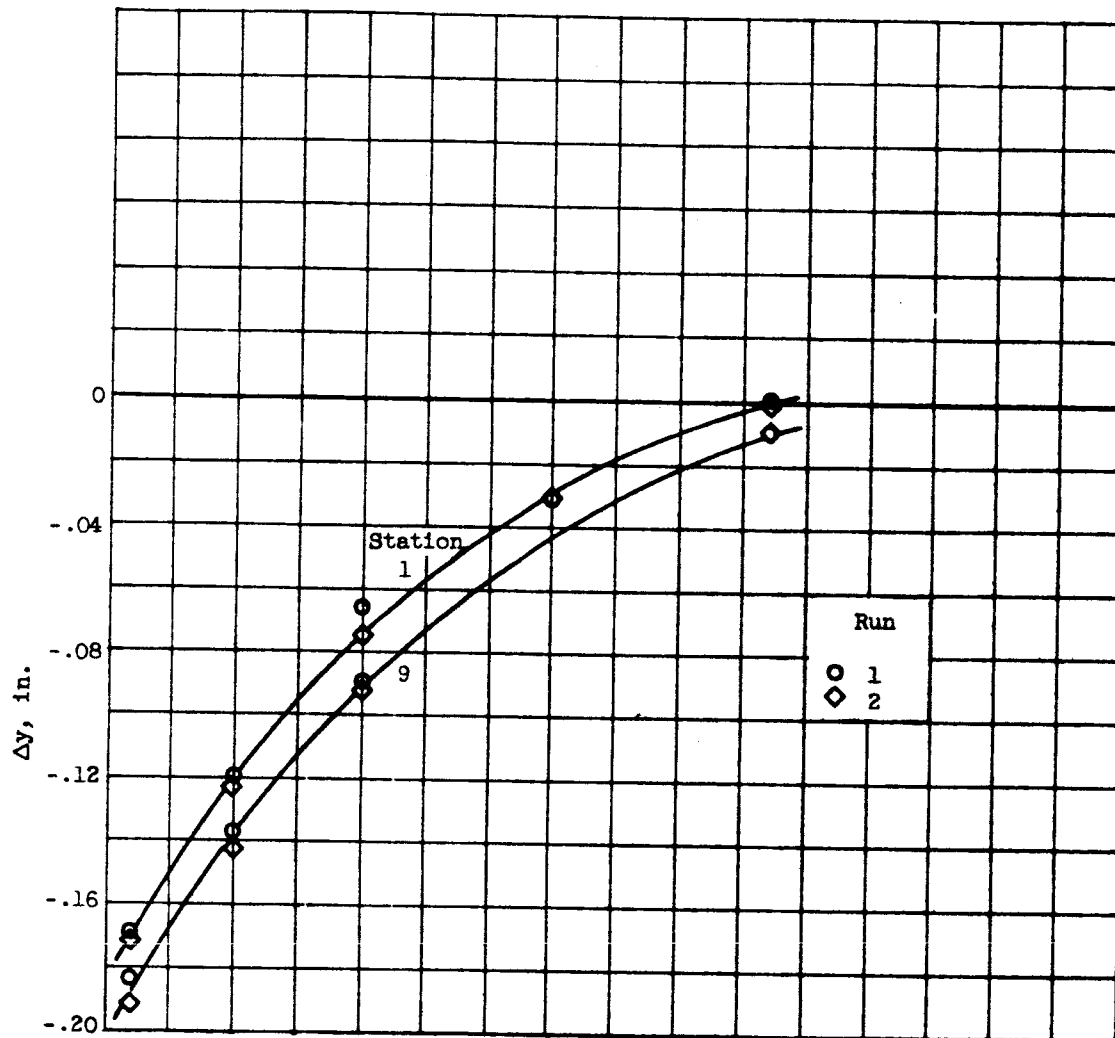
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TABLE I - TEMPERATURES
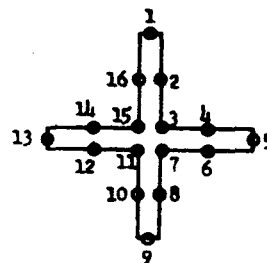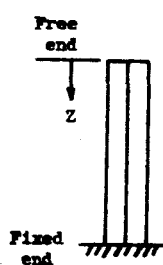
Z (in.)	Run	Thermocouple location															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1	449	448	426	429	414	418	419	398	387	400	395	415	409	358	426	449
	2	444	446	433	431	422	425	412	404	366	386	387	414	401	369	407	444
	3	450	457	455	470	460	462	466	466	465	466	465	465	445		459	458
8	1	450				430	436	421	393	388				421	421	421	445
	2	445				435	435	424	388	385				408	407	405	425
	3	439				459	459	452	460	470				451	452	440	442
15	1	451	452	443	448	447	445	430	423	430	416		440	446	445	440	455
	2	454	456	454	453	453	453	437	432	429			451	450	450	450	455
	3	430	430	429	441	441	441	438	456	460			447	448	447	431	432
22	1	454				435	430	413	412	416				439	369	430	424
	2	454				432	433	420	409	395				406	377	406	406
	3	416				428	430	425	447	450				404		417	
29	1	463	457	430	450	453	452	432	430	418	429	420	436	434	437	435	454
	2	469	463	453	456	459	459	452	444	435	435	410	413	444	415	441	457
	3	439	436	431	451	455	455	439	458	460	469	449	448	448	445	439	435
36	1	465				439	430	420	419	415				451	450	441	455
	2	466				444	434	417	407	406				442	419	426	457
	3	430				442	442	439	461	462				451	447	438	425
43	1	464	461	447	452	462	454	428	431	442	430	437	460	463	460	451	463
	2	474	474	470	470	470	470	439	444	449	449	449	464	470	470	469	469
	3	430	425	423	437	447	443	429	450	467	460	430	435	437	434	422	430
50	1	457				405	415	415	426	406				410	422	433	454
	2	469				407	407	405	408	406				405	414	444	461
	3	423				428	439	458	481	466				432	441	458	447

TABLE II - DISTORTION
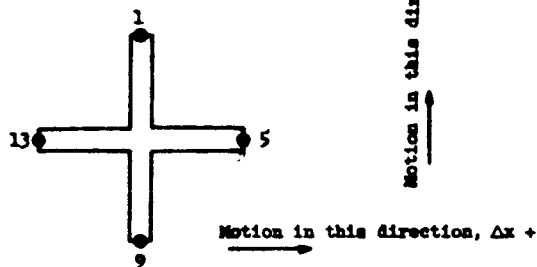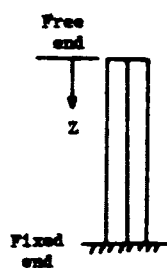
Z (in.)	Run	Displacement (in.)	Gage location			
			1	5	9	13
2	1	Δx	-0.007	0.004	-0.001	-0.009
		Δy	-.168	-.177	-.183	-.173
	2	Δx	-.011	-.009	-.019	-.027
		Δy	-.171	-.185	-.191	-.171
	3	Δx	-.014	-.005	-.023	-.022
		Δy	.172	.160	.152	.159
10	1	Δx	-.004	.004	-.009	.003
		Δy	-.120	-.127	-.137	-.118
	2	Δx	-.010	.000	-.035	-.010
		Δy	-.123	-.131	-.142	-.128
	3	Δx	-.008	-.003	-.003	-.016
		Δy	.124	.115	.108	.121
20	1	Δx	.003	.007	-.004	-.001
		Δy	-.066	-.082	-.089	-.077
	2	Δx	-.002	-.001	.009	-.007
		Δy	-.074	-.082	-.092	-.082
	3	Δx	.017	.007	.006	-.007
		Δy	.075	.064	.060	.030
35	1	Δx	-.003	.006	———	-.006
		Δy	-.031	———	———	———
	2	Δx	-.008	.002	———	-.008
		Δy	-.031	———	———	———
	3	Δx	.018	.009	-.001	-.003
		Δy	.021	———	———	———
52	1	Δx	———	.003	———	-.003
		Δy	.001	———	-.010	———
	2	Δx	———	.002	———	-.001
		Δy	-.002	———	-.008	———
	3	Δx	———	.005	———	-.002
		Δy	.002	———	-.005	———

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(a) Variation of Δy with Z.

(b) Variation of Δx with Z.

Figure 1. - Distortion of control rod with maximum temperature
occurring at station 1. Runs 1 and 2.
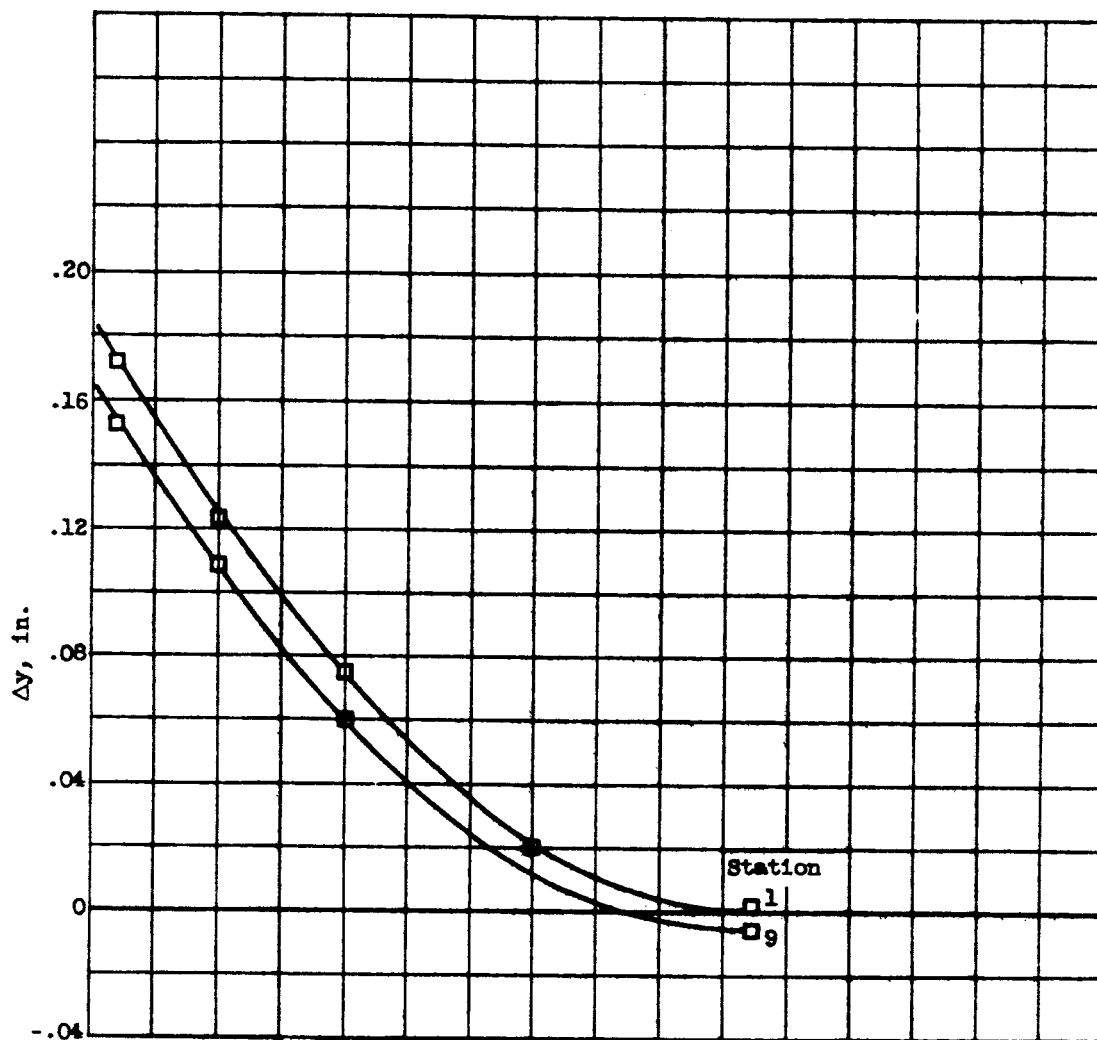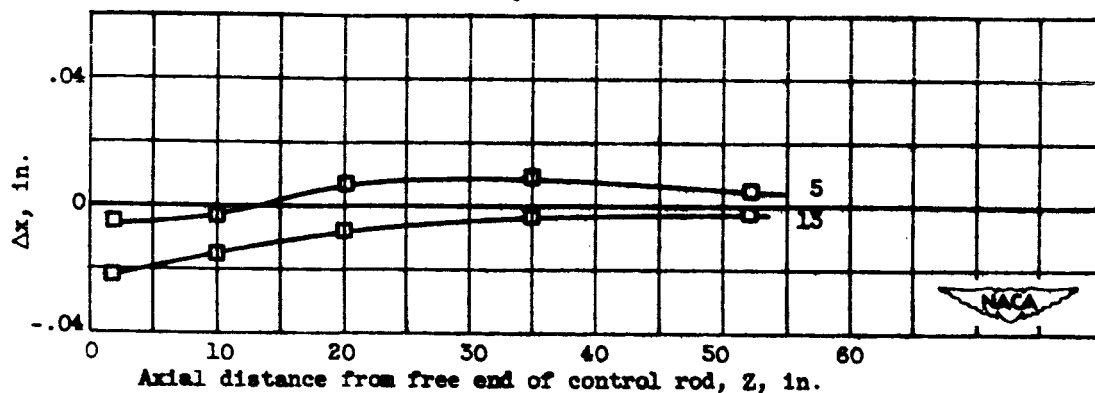
(a) Variation of Δy with Z.

(b) Variation of Δx with Z.

Axial distance from free end of control rod, Z, in.

Figure 2. - Distortion of control rod with maximum temperature occurring at station 9. Run 3.